DRAFT

Conjunctive Use Site Assessment

CALFED Bay-Delta Program
1416 Ninth Street, Suite 1155
Sacramento, California 95814

916-657-2666

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Integrated Storage Investigation

CALFED BAY-DELTA PROGRAM

Introduction

The CALFED Bay-Delta Program is refining a Water Management Strategy to provide broad guidance for selecting and implementing water management tools over the implementation phase of the Program, in consideration of all Program objectives. To provide a basis for evaluating alternative water management strategies, CALFED is developing and implementing a Water Management Strategy Evaluation Framework (WMSEF). This framework is designed to support the decision-making process and help arrive at a broadly supportable Water Management Strategy. It focuses on: (1) establishing a comprehensive list of performance measures (or evaluation criteria) that can be used to compare the relative value of alternatives, and (2) encouraging a creative approach to the development of the successful alternative strategies.

In support of the WMSEF effort, CALFED recently performed an Economic Evaluation of Water Management Alternatives (EEWMA) to analyze the water management benefits and costs of alternative water management options. This effort is documented in a report entitled the *Economic Evaluation of Water Management Alternatives Screening Analysis* (CALFED, October 1999). The EEWMA revealed that conjunctive use might be one of the most cost-effective and desirable tools in the array of potential water management strategies. Conjunctive use is defined as the coordinated management of surface water and groundwater to help increase overall water supply reliability. Groundwater banking is a form of conjunctive use that involves the storage of surplus or wet-year water in groundwater basins that have existing storage space.

To provide more accurate information for consideration in the WMSEF, CALFED is refining estimates of the physical characteristics, benefits, potential impacts, and costs for a variety of water management tools, including conjunctive use. A technical workgroup was assembled in September 1999 to develop a preliminary list of conjunctive use sites that could be used in the WMSEF analyses. The workgroup included representatives of the Natural Heritage Institute (NHI), CALFED agency staff, and other experts in water management and conjunctive use.

This report presents a summary of the workgroup's approach and a description of the key parameters that will be used for the modeling analyses.

Approach

In order to compare conjunctive use with other potential water management strategies, CALFED required additional information on the following parameters:

- Storage capacities of potential conjunctive use and groundwater banking sites to the north and to the south of the Sacramento-San Joaquin Delta.
- Recharge and recovery rates associated with each potential site.
- Costs associated with storing and recovering water at each of the potential sites.

Given the accelerated implementation schedule of the WMSEF, the workgroup was given approximately three months to develop the required information. This relatively short timeframe obliged the workgroup to develop a reconnaissance level assessment strategy to develop a list of sites that could be used in programmatic level modeling analyses. This list is not intended to be a definitive suite of potential conjunctive use projects in California.

The process used to develop the initial list and the parameters for each site is presented below.

Step 1: Defining a Suite of Potential Sites

The first activity undertaken by the workgroup was to develop a list of potential groundwater banking sites in the State. Working from the inventory included in NHI's *Feasibility Study of a Maximal Groundwater Banking Program for California* and candidate projects suggested by other workgroup members, the group developed an initial suite of sites that included various conjunctive use opportunities. These included groundwater basins with existing storage space as well as basins where substantial aquifer recharge creates the potential for more active management of the groundwater resource.

Running roughly from north to south, the initial list of potential sites included:

- Stony Creek Alluvial Fan
- Butte Basin
- Sutter Basin
- Cache-Putah Basin (Conaway Ranch)
- Sacramento North Area
- South Sacramento County
- San Joaquin County
- Alameda County
- Santa Clara County
- Tuolumne-Merced River Region
- Madera Ranch
- Kings River Alluvial Fan
- Kern Water Bank
- Arvin-Edison Water Storage District
- Semitropic Water District
- Mojave River Basin
- Raymond Basin
- West-Central Basin
- Chino Basin

Recognizing that physical and cost analyses for each of these sites could not be completed within the given timeframe, the above list was shortened to include only those projects that met the following additional criteria:

- The recommendations of an earlier conjunctive use investigation completed for the U.S. Bureau of Reclamation (CH2MHill, 1995) regarding the hydrologic promise of groundwater basins in the Central Valley.

- The collective professional judgment of the workgroup regarding the technical and political feasibility of each potential site.

The relative feasibility of a potential project was assessed primarily on the basis of whether local agencies in a basin had begun to formulate their own plans for conjunctive use. As a result of this screening, the following sites were chosen for subsequent analyses:

- Stony Creek Fan
- Butte Basin
- Cache-Putah Basin (Conaway Ranch)
- Sacramento North Area
- South Sacramento County
- San Joaquin County
- Madera Ranch
- Kings River Alluvial Fan
- Kern Water Bank

The geographic location and distribution of these sites within the Central Valley is presented in Figure 1.

Step 2: Estimating the Available Storage Capacity of the Projects

Having completed the initial screening of sites, the workgroup developed a strategy to estimate the storage capacity at each of the selected sites. Ideally, estimating the operational capacity of a conjunctive use project should rely upon transient analysis of recharge and recovery of project operations. This type of analysis would allow for consideration of:

- The impact of storage and recovery operations on the other components of the water balance for a groundwater basin (e.g. surface water and groundwater interactions).
- The impact of storage and recovery operations on existing groundwater users in the basin.
- The potential to manage the overall basin response to storage and recovery operations by raising groundwater levels beyond the limits of existing drawdown features.
- Any losses that might be associated with storage and recovery operations.

The best way to consider these issues is through the development and operation of appropriate groundwater models. While the workgroup's efforts did not allow for this level of analysis, groundwater models will be developed as part of ongoing investigations of conjunctive use in the Central Valley.

The workgroup's estimation of the storage capacity of the potential projects was based on static geometric analysis of existing drawdown features. Working from DWR water level elevation maps for Fall 1992, the total unsaturated volume within a drawdown feature was adjusted by an estimate of the specific yield taken from the Central Valley Groundwater/Surface Water Model (CVGSM). The result was an estimate of the available water storage capacity.

By its very nature this approach is extremely conservative since existing drawdown features were treated as "tanks" of fixed dimensions within which water could be stored. No assessment was made of the potential to increase the capacity of a tank by raising the water level around a depression. This geometric analysis was applied to the following sites:

- Sacramento North Area
- South Sacramento County (two draw down features were considered)
- San Joaquin County
- Madera Ranch
- Kings River Fan

Given the advanced level of development at the Kern Water Bank, the workgroup decided that application of this static approach was probably inappropriate. Instead an inquiry was made to the Kern County Water Agency regarding their assessment of the available storage capacity for that project.

A static geometric analysis to estimate the storage capacity of potential sites in the Sacramento Valley (Stony Creek Fan, Butte Basin, Cache-Putah Basin) was not appropriate since these sites do not have significant existing storage space. Instead, potential capacities were estimated based largely on the observed response of groundwater basins in the Sacramento Valley to various levels of pumping.

Table 1 presents the results of the workgroup's evaluation of storage capacities for the selected sites. Figures 2 through 11 contain maps of each site location.

Table 1: Estimates of Potential Storage Capacity at Selected Conjunctive Use Project Sites in the Central Valley

Storage Site	Unsaturated Volume (ac-ft)	Assume S_y[2.] = 0.1 Potential Storage (ac-ft)	Assume S_y = 0.2 Potential Storage (ac-ft)
Stoney Creek[1.]		200000	200000
Butte Basin[1.]		200000	200000
Conway Ranch[1.]		200000	200000
Sacramento North Area	1855040	185504	371008
S. Sacramento Co./Elk Grove	3884160	388416	776832
S. Sacramento Co./Galt	2315520	231552	463104
San Joaquin County	2326720	232672	465344
Madera Ranch	2867200	286720	573440
Kings River Fan	4346784	434678	869357
Kern Water Bank[3.]		1200000	1200000
Total Storage		2959542	4719085

[1.] The potential storage for these sites is assumed to equal 200 TAF after the native groundwater has been developed.

[2.] The CVGSM model assumes that specific yield ranges from 0.08 and 0.12 over several large parametric elements. In keeping with this data, the first column assumes that Sy equals 0.1 while the second column assumes that in areas suitable for groundwater banking the value may increase to 0.2.

[3.] Data for the Kern Water Bank was developed by the Kern County Water Agency

These values formed the basis of the workgroup's recommendations of the total conjunctive use storage capacity to use in the WMSEF model runs.

Step 3: Estimating Appropriate Recharge and Recovery Rates for the Projects

In addition to the storage capacity, the WMSEF efforts require information on appropriate recharge and recovery rates for the selected projects. For the purposes of this analysis, appropriate recharge and recovery rates were developed from known recharge and recovery rates experienced at other sites. These data are shown in Table 2.

Table 2: Estimates of Appropriate Recharge and Recovery Rates at Selected Conjunctive Use Project Sites in the Central Valley

Storage Site	CVGSM Hydraulic Conductivity (ft/day)	Assume $S_y = 0.1$ Potential Storage (ac-ft)	Recharge/ Recovery[1] (ac-ft/day)	Assume $S_y = 0.2$ Potential Storage (ac-ft)	Recharge/ Recovery (ac-ft/day)
Stoney Creek	60	200000	960	200000	960
Butte Basin	30	200000	480	200000	480
Conway Ranch	38	200000	608	200000	608
Sacramento North Area	28	185504	416	371008	831
S. Sacramento Co./Elk Grove	28	388416	870	776832	1740
S. Sacramento Co./Galt	28	231552	51[illegible]	463104	1037
San Joaquin County	120	232672	2234	465344	4467
Madera Ranch[2]	50	286720	1147	573440	2294
Kings River Fan	50	434678	1739	869357	3477
Kern Water Bank[3]	50	800000	3200	800000	3200
Total Storage		2559542		4319085	

[1] Assumes that recharge occurs at a rate of 0.004 ac-ft/day/ac-ft of storage at Madera Ranch with the rate being adjusted at other sites based on the ratio of the CVGSM hydraulic conductivity at that site to the hydraulic conductivity at Madera Ranch

[2] Pump test conducted at Madera Ranch found that the hydraulic conductivity ranged from 50-95 ft/day

[3] Data for the Kern Water Bank was developed by the Kern County Water Agency

Step 4: Screen the Potential Projects for the WMSEF Based on CALFED Policy

Values in Table 1 and 2 were screened further to select alternatives that could be represented adequately in a limited number of comprehensive programmatic model runs. This screening was performed to eliminate potential projects deemed too politically controversial to be included in the initial set of WMSEF alternatives and refine estimates of recharge and recovery rates based on an assessment of land use constraints on the remaining projects.

Potential projects at Stony Creek, Butte Basin, and the Cache-Putah Basin (Conaway Ranch) were eliminated because these aquifers are generally full. Using these aquifers conjunctively would require initial extraction followed by active or passive recharge. These may prove to be attractive projects in the future if potential third-party impacts are addressed adequately.

The Sacramento North Area was also eliminated based on the supposition the Sacramento North Area Groundwater Management Agency would fully utilize the storage potential at this site.

The second objective of refining recharge and extraction rates led to limiting recharge at the South Sacramento County sites to 0.5 feet/day spread over 1 square mile, increasing 250 cfs during the growing season to account for *in lieu* possibilities. Assuming one 1,500 gpm well per 10 acres at the project site, the recovery rate in South Sacramento County was set at 200 cfs. The workgroup considered projects in the San Joaquin Valley to be less constrained by competing land-use considerations.

The remaining sites and associated values will be simulated in evaluations associated with the WMSEF as shown in Table 3.

Table 3: Aggregate Conjunctive Use "Projects" and Associated Sites

Project	Storage	Recharge Oct-Apr	Recharge May-Sept	Retrieval
North of Delta				
So. Sacramento County	500 TAF	150 cfs	250 cfs	200 cfs
South of Delta				
San Joaquin County	500 TAF	250 cfs	350 cfs	200 cfs
Madera Ranch	300 TAF	400 cfs	400 cfs	200 cfs
Kings River Fan	500 TAF	250 cfs	350 cfs	200 cfs
Kern Water Bank	500 TAF	250 cfs	350 cfs	200 cfs

Aggregating the remaining potential projects results in total conjunctive use storage volumes of 1.8 MAF south of the Delta and 500 TAF north of the Delta. These values will be used in formulating alternative water management strategies that emphasize conjunctive use to other water management strategies in the WMSEF.

Step 5: Developing Costs for the Projects

Order-of-magnitude cost estimates were prepared for each of the selected sites. These cost estimates were based on available data to compare the potential costs associated with developing each project. Approach to the cost estimate included:

- Flow rates of 250 cfs, 400 cfs, 1000 cfs, and 4000 cfs
- Groundwater recharge either by spreading basin (alternative 1) or a combination of spreading basins and groundwater injection using the wells that would be installed for groundwater extraction (alternative 2).
- A cycle of recharge for 3 months for 5 of 7 years and annual extraction of 4 months for 7 years
- A 10 percent loss to the local groundwater system.

Summaries of the approach and assumptions used to develop the cost estimate, as well as site specific summaries of the capital and operations and maintenance (O&M) for each site, are included in Attachment A.

The cost estimate evaluation focused on 400 cfs at a recharge rate of 0.5 ft/day because implementation of a project of this size was considered by the workgroup to have a higher potential than projects of larger or smaller size. Additionally, the recharge rate of 0.5 ft/day was assumed to reasonably represent potential project recharge rates, although this rate can vary significantly based on local conditions.

Evaluation of the total annualized costs for 250 cfs and 400 cfs (recharge of 0.5 ft/day) show that there are minimal differences in capital costs between alternatives 1 and 2. These costs are summarized in Tables 4 and 5. Length of the conveyance facilities and land costs were the most significant factors in the costs differences between the sites. Further comparison of estimated project costs are shown in:

- *Figure 12* - cost variations for the project alternatives 1 and 2 for 400 cfs and 0.5 ft/day
- *Figure 13* - total capital costs for basins and wells at 400 and 1000 cfs
- *Figure 14* - estimated project capital costs assuming a flow rate of 400 cfs, recharge by both spreading basins and wells, and a recharge rate of 0.5 ft/day.
- *Figure 15* – total estimated project cost per acre-foot of recovered water, assuming a project life of 30 years

Conclusions

The results presented in this report were derived using approximate methods to allow analysis of conjunctive use impacts within the CALFED programmatic water management strategy. A large number of potential conjunctive use sites were screened to select a small set of particularly promising locations to be used in the first set of WMSEF alternative water management strategies. If results from the first set of WMSEF alternatives indicate that a more aggressive conjunctive use component could improve the overall performance of a water management strategy, additional conjunctive use sites will be included in future analyses.

Table 4: Total Capital and Annual Cost Development for Spreading Basins

Spreading Basin (assumed recharge rate of 0.5 ft/day)

All values in millions of dollars

Site	Base Construction Estimate	Contingency Cost	Construction Cost	Engineering Cost	Regulatory Cost	Total CapitalCost	Annual Capital Cost	Annual O&M Cost	Annual Energy Cost	TOTAL ANNUAL COST
A	B	C	D	E	F	G	J	K	L	M
		0.2 x B	B + C	0.35 x D	0.2 x D	D + E + F				J + K + L
Stoney Creek-Glenn Colusa										
Flow rate= 250 cfs	32.43	6.49	38.92	13.62	7.78	60.32	$4.38	1.17	1.07	6.62
Flow rate= 400 cfs	48.55	9.71	58.26	20.39	11.65	90.30	$6.56	1.75	1.72	10.03
Stoney Creek-Tehama Colusa										
Flow rate= 250 cfs	26.19	5.24	31.43	11.00	6.29	48.71	$3.54	0.94	1.04	5.52
Flow rate= 400 cfs	41.25	8.25	49.50	17.33	9.90	76.73	$5.57	1.49	1.67	8.73
Butte Basin										
Flow rate= 250 cfs	38.20	7.64	45.84	16.04	9.17	71.05	$5.16	1.38	1.01	7.55
Flow rate= 400 cfs	56.81	11.36	68.17	23.86	13.63	105.67	$7.68	2.05	1.63	11.35
Conway Ranch										
Flow rate= 250 cfs	27.35	5.47	32.82	11.49	6.56	50.87	$3.70	0.98	0.98	5.66
Flow rate= 400 cfs	43.04	8.61	51.65	18.08	10.33	80.05	$5.82	1.55	1.58	8.95
Elk Grove-Sacramento										
Flow rate= 250 cfs	32.27	6.45	38.72	13.55	7.74	60.02	$4.36	1.16	1.01	6.53
Flow rate= 400 cfs	49.66	9.93	59.59	20.86	11.92	92.37	$6.71	1.79	1.63	10.13
Elk Grove-Consumnes										
Flow rate= 250 cfs	30.93	6.19	37.12	12.99	7.42	57.53	$4.18	1.11	1.01	6.30
Flow rate= 400 cfs	48.12	9.62	57.74	20.21	11.55	89.50	$6.50	1.73	1.63	9.86
Galt-Consumnes										
Flow rate= 250 cfs	30.67	6.13	36.80	12.88	7.36	57.05	$4.14	1.10	1.04	6.29
Flow rate= 400 cfs	47.11	9.42	56.53	19.79	11.31	87.62	$6.37	1.70	1.67	9.73
Galt- Sacramento										
Flow rate= 250 cfs	41.53	8.31	49.84	17.44	9.97	77.25	$5.61	1.50	1.10	8.21
Flow rate= 400 cfs	60.87	12.17	73.04	25.57	14.61	113.22	$8.23	2.19	1.77	12.19
San Joaquin-Mokelumne										
Flow rate= 250 cfs	28.76	5.75	34.51	12.08	6.90	53.49	$3.89	1.04	0.98	5.90
Flow rate= 400 cfs	45.26	9.05	54.31	19.01	10.86	84.18	$6.12	1.63	1.58	9.33
San Joaquin-Calaveras										
Flow rate= 250 cfs	31.11	6.22	37.33	13.07	7.47	57.86	$4.20	1.12	1.04	6.36
Flow rate= 400 cfs	48.34	9.67	58.01	20.30	11.60	89.91	$6.53	1.74	1.67	9.94
Madera Ranch										
Flow rate= 250 cfs	36.69	7.34	44.03	15.41	8.81	68.24	$4.96	1.32	1.13	7.41
Flow rate= 400 cfs	54.59	10.92	65.51	22.93	13.10	101.54	$7.38	1.97	1.81	11.15
Kings River Fan										
Flow rate= 250 cfs	45.48	9.10	54.58	19.10	10.92	84.59	$6.15	1.64	1.21	8.99
Flow rate= 400 cfs	64.83	12.97	77.80	27.23	15.56	120.58	$8.76	2.33	1.95	13.04
Kern Water Bank										
Flow rate= 250 cfs	38.64	7.73	46.37	16.23	9.27	71.87	$5.22	1.39	1.10	7.71
Flow rate= 400 cfs	56.89	11.38	68.27	23.89	13.65	105.82	$7.69	2.05	1.77	11.51

Table 5: Total Capital and Annual Cost Development for Spreading Basins and Groundwater Injection

Spreading Basin (assumed recharge rate of 0.5 ft/day) and Groundwater Injection Recharge

All values in millions of dollars

Site	Base Construction Estimate	Contingency Cost	Construction Cost	Engineering Cost	Regulatory Cost	Total CapitalCost	Annual Capital Cost	Annual O&M Cost	Annual Energy Cost	TOTAL ANNUAL COST
A	B	C	D	E	F	G	J	K	L	M
		0.2 x B	B + C	0.35 x D	0.2 x D	D + E + F				J +K + L
Stoney Creek-Glenn Colusa										
Flow rate= 250 cfs	34.24	6.85	41.08	14.38	8.22	63.68	$4.63	1.23	1.40	7.26
Flow rate= 400 cfs	50.08	10.02	60.09	21.03	12.02	93.14	$6.77	1.80	2.25	10.82
Stoney Creek-Tehama Colusa										
Flow rate= 250 cfs	27.90	5.58	33.48	11.72	6.70	51.89	$3.77	1.00	1.37	6.14
Flow rate= 400 cfs	42.62	8.52	51.15	17.90	10.23	79.28	$5.76	1.53	2.20	9.49
Butte Basin										
Flow rate= 250 cfs	39.08	7.82	46.89	16.41	9.38	72.68	$5.28	1.41	1.34	8.03
Flow rate= 400 cfs	56.98	11.40	68.38	23.93	13.68	105.99	$7.70	2.05	2.16	11.91
Conway Ranch										
Flow rate= 250 cfs	29.00	5.80	34.80	12.18	6.96	53.95	$3.92	1.04	1.31	6.27
Flow rate= 400 cfs	44.33	8.87	53.19	18.62	10.64	82.45	$5.99	1.60	2.11	9.70
Elk Grove-Sacramento										
Flow rate= 250 cfs	33.58	6.72	40.29	14.10	8.06	62.46	$4.54	1.21	1.34	7.09
Flow rate= 400 cfs	50.37	10.07	60.44	21.16	12.09	93.69	$6.81	1.81	2.16	10.78
Elk Grove-Consumnes										
Flow rate= 250 cfs	32.33	6.47	38.80	13.58	7.76	60.13	$4.37	1.16	1.34	6.87
Flow rate= 400 cfs	48.93	9.79	58.71	20.55	11.74	91.00	$6.61	1.76	2.16	10.53
Galt-Consumnes										
Flow rate= 250 cfs	32.39	6.48	38.86	13.60	7.77	60.24	$4.38	1.17	1.37	6.91
Flow rate= 400 cfs	48.51	9.70	58.22	20.38	11.64	90.23	$6.56	1.75	2.20	10.50
Galt- Sacramento										
Flow rate= 250 cfs	42.72	8.54	51.26	17.94	10.25	79.45	$5.77	1.54	1.43	8.74
Flow rate= 400 cfs	61.49	12.30	73.78	25.82	14.76	114.36	$8.31	2.21	2.30	12.82
San Joaquin-Mokelumne										
Flow rate= 250 cfs	30.25	6.05	36.29	12.70	7.26	56.26	$4.09	1.09	1.31	6.49
Flow rate= 400 cfs	46.21	9.24	55.46	19.41	11.09	85.96	$6.24	1.66	2.11	10.02
San Joaquin-Calaveras										
Flow rate= 250 cfs	32.41	6.48	38.89	13.61	7.78	60.28	$4.38	1.17	1.37	6.92
Flow rate= 400 cfs	49.07	9.81	58.89	20.61	11.78	91.28	$6.63	1.77	2.20	10.60
Madera Ranch										
Flow rate= 250 cfs	37.93	7.59	45.51	15.93	9.10	70.55	$5.13	1.37	1.46	7.95
Flow rate= 400 cfs	55.29	11.06	66.35	23.22	13.27	102.83	$7.47	1.99	2.34	11.80
Kings River Fan										
Flow rate= 250 cfs	47.08	9.42	56.49	19.77	11.30	87.56	$6.36	1.69	1.54	9.60
Flow rate= 400 cfs	66.07	13.21	79.28	27.75	15.86	122.89	$8.93	2.38	2.48	13.79
Kern Water Bank										
Flow rate= 250 cfs	39.98	8.00	47.98	16.79	9.60	74.36	$5.40	1.44	1.43	8.27
Flow rate= 400 cfs	57.66	11.53	69.19	24.22	13.84	107.24	$7.79	2.08	2.30	12.17

Figure 1

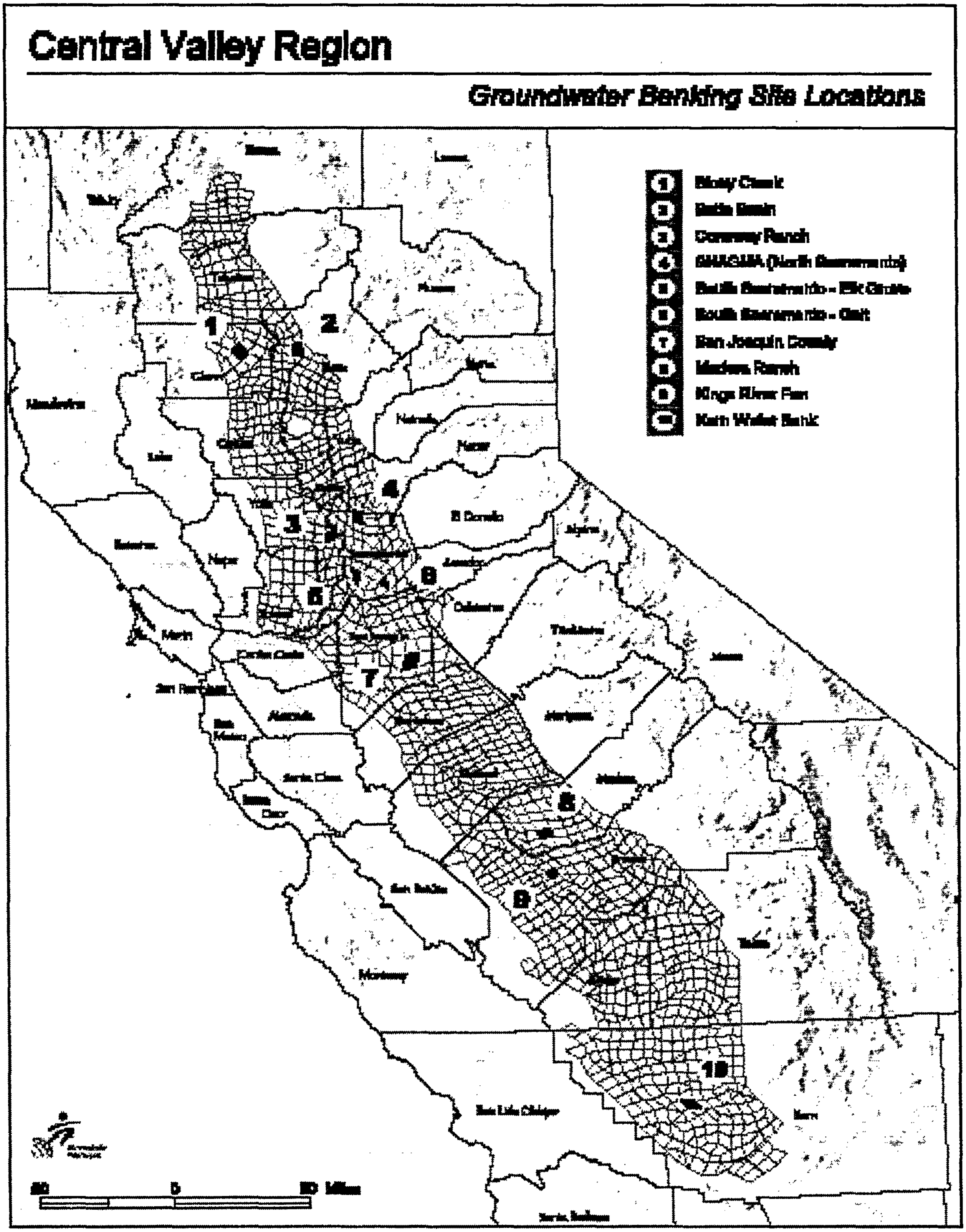

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Figure 2

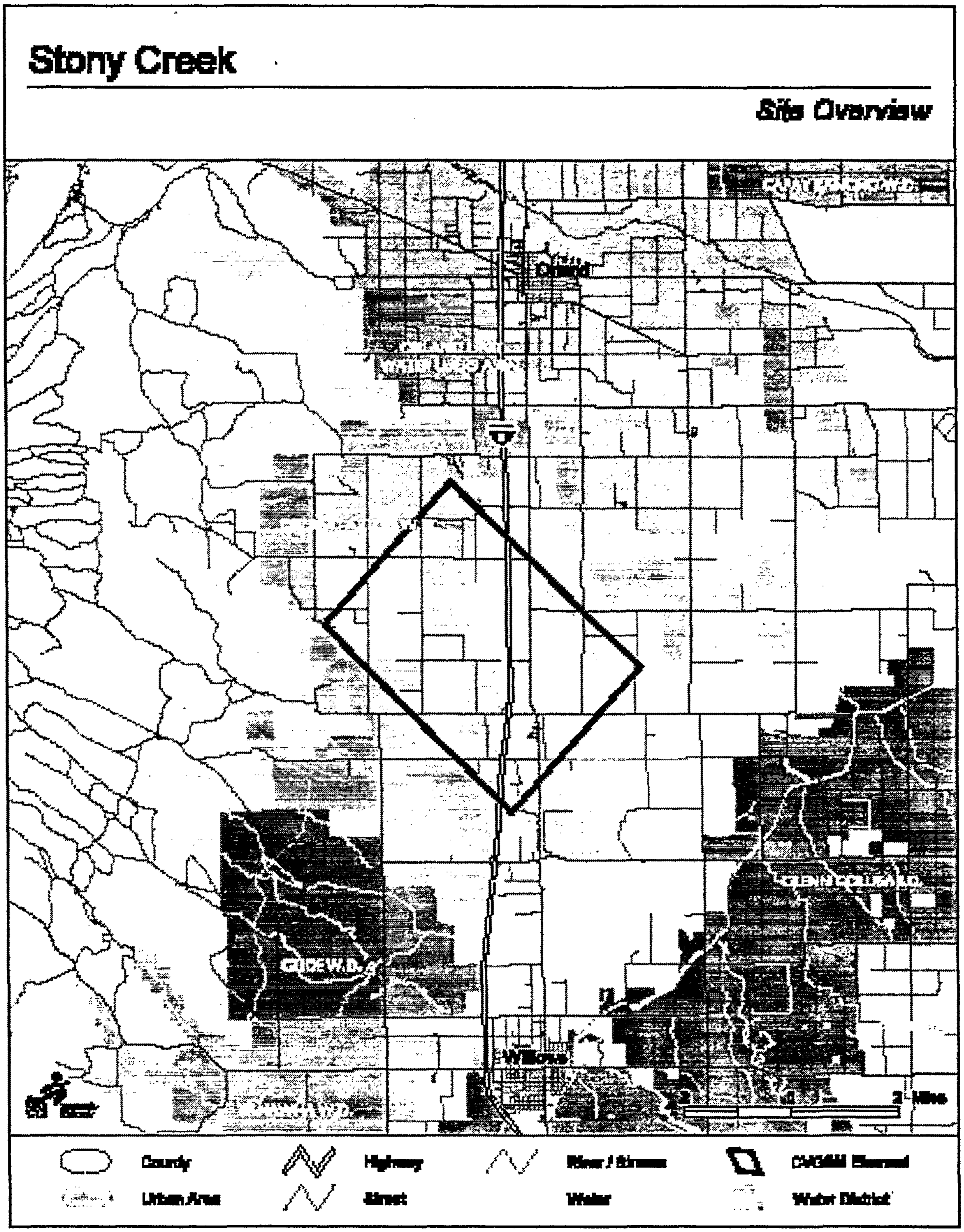

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Figure 3

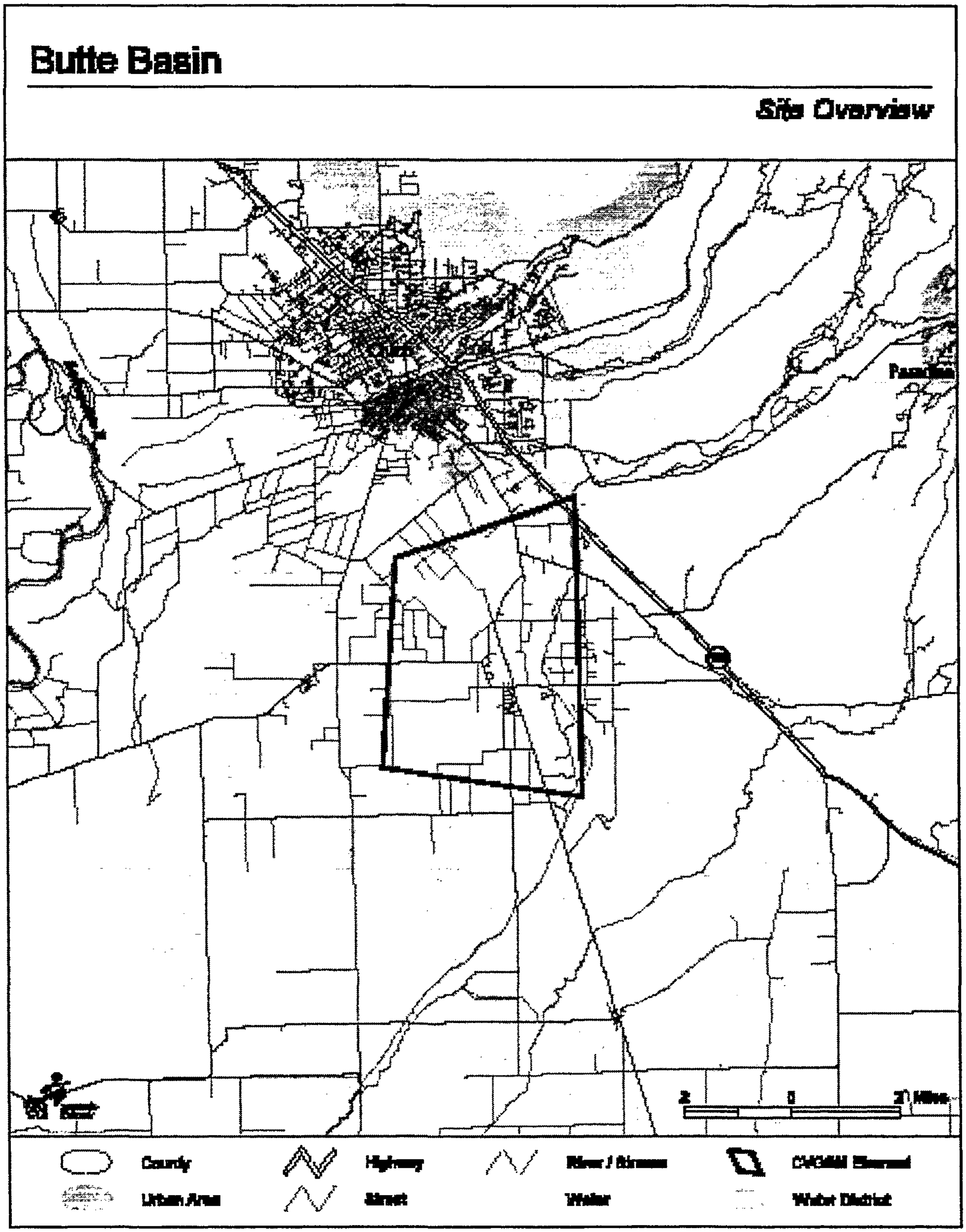
Butte Basin
Site Overview
County
Highway
River / Stream
Urban Area
Street
Water
Water District
2
0
2 Miles

Figure 4

Conaway Ranch

Site Overview

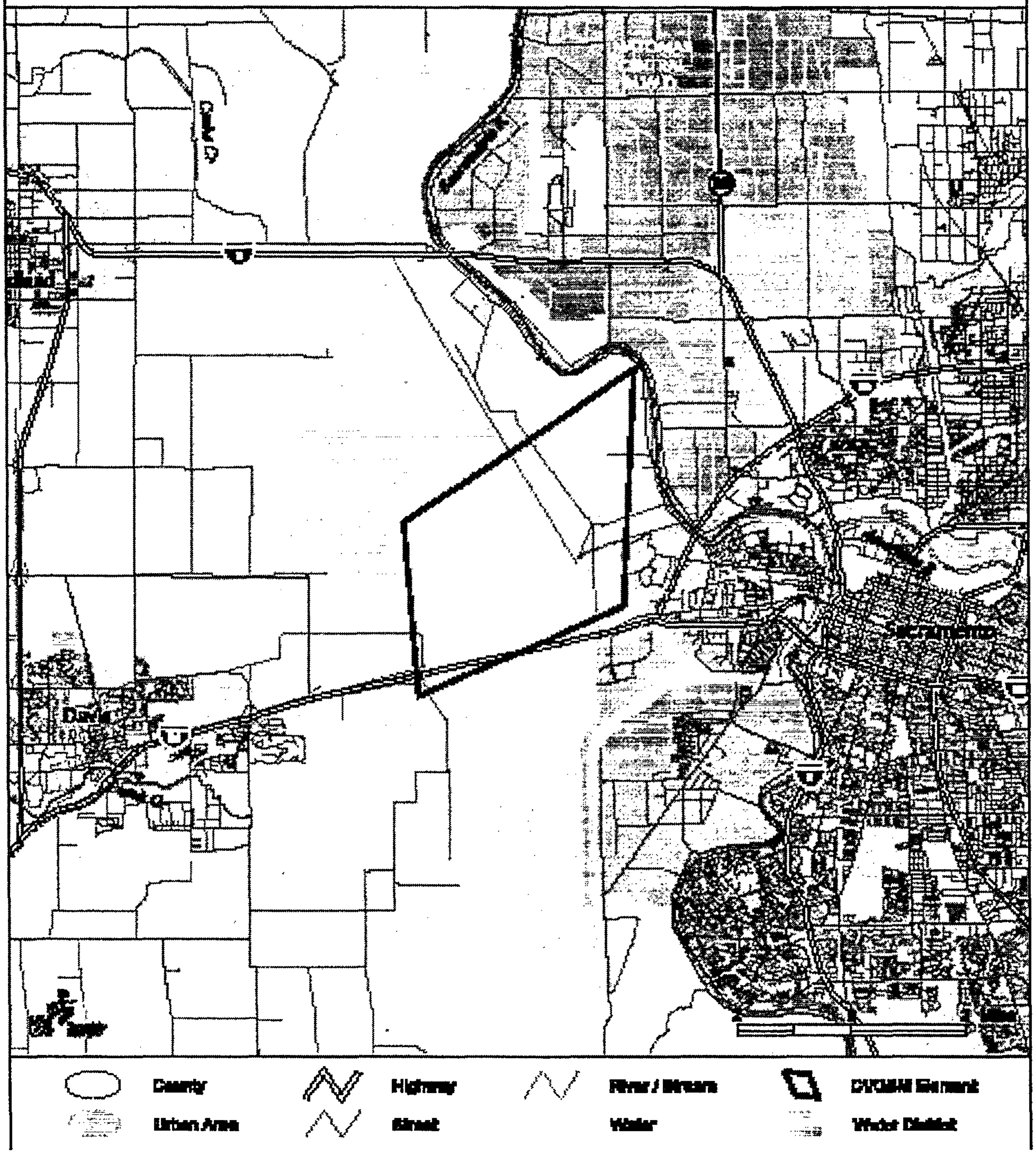

Figure 5

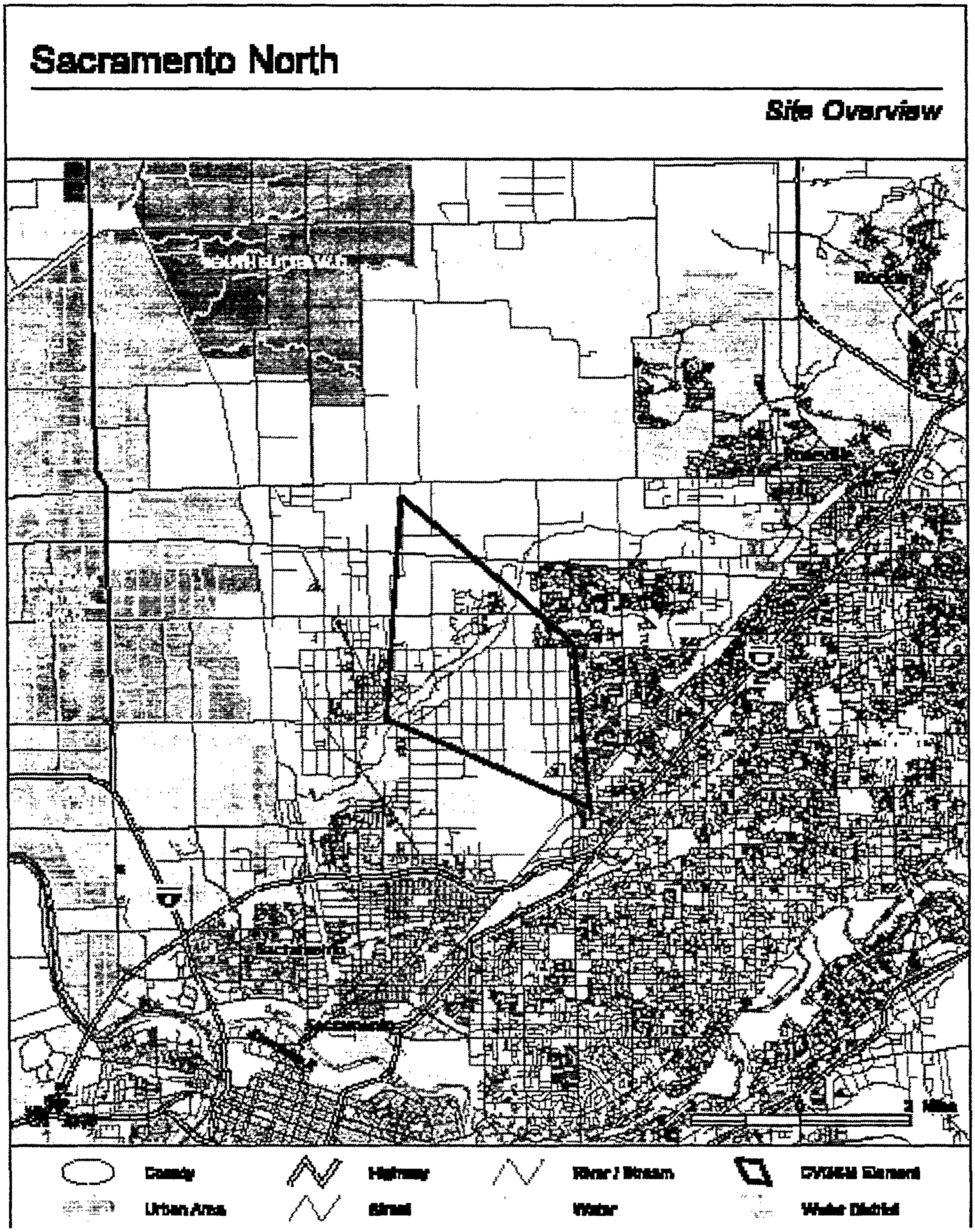

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Figure 6

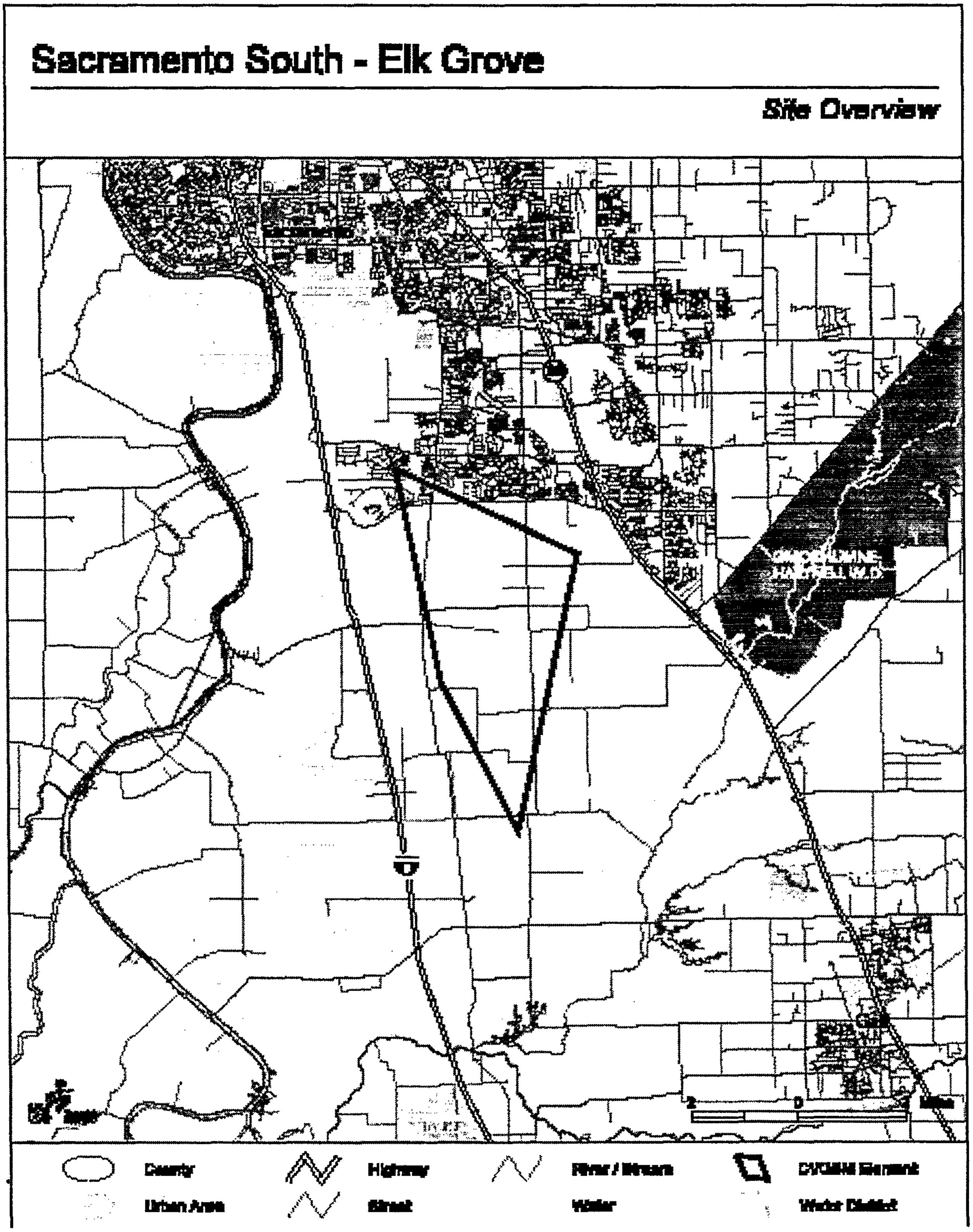

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Figure 7

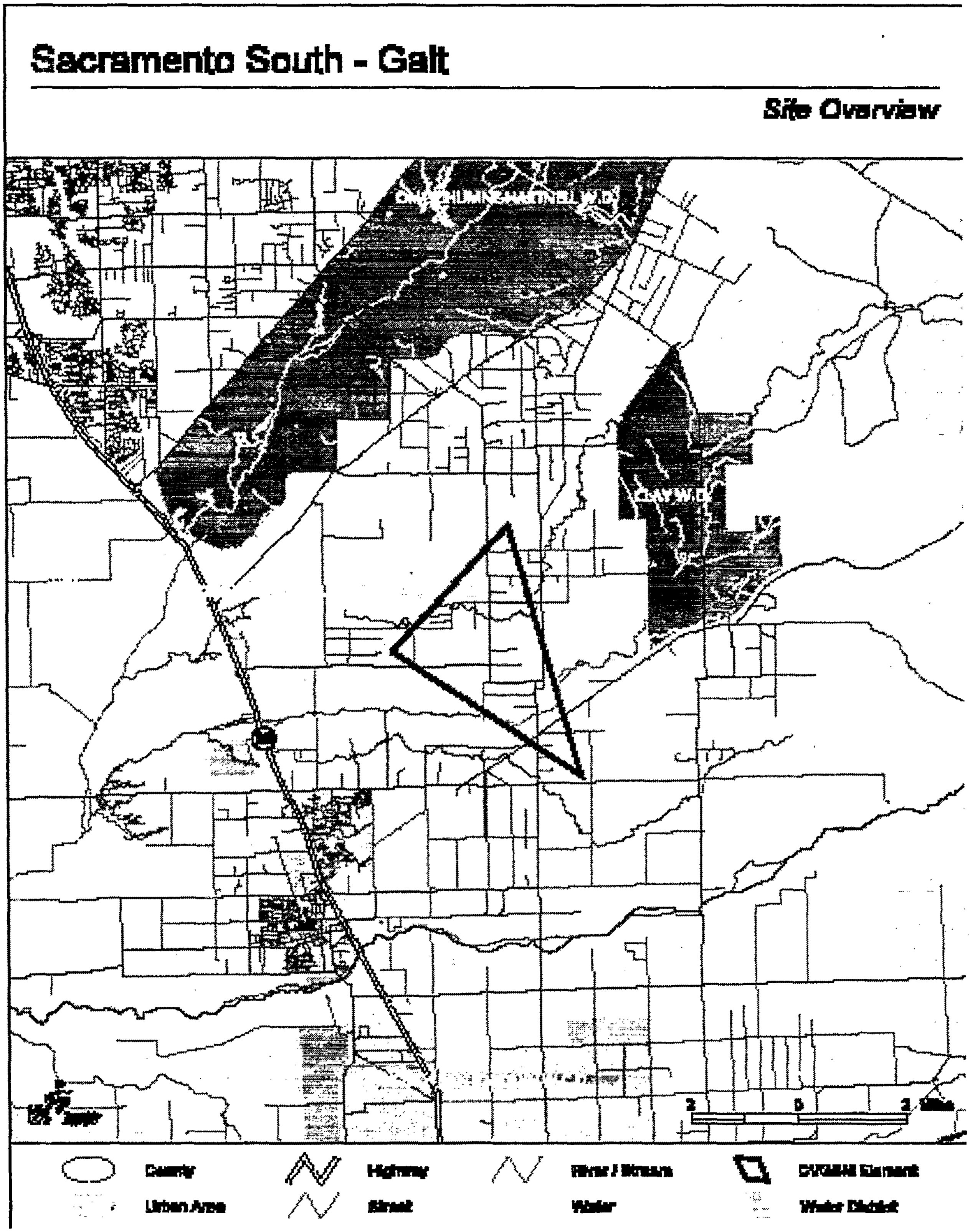

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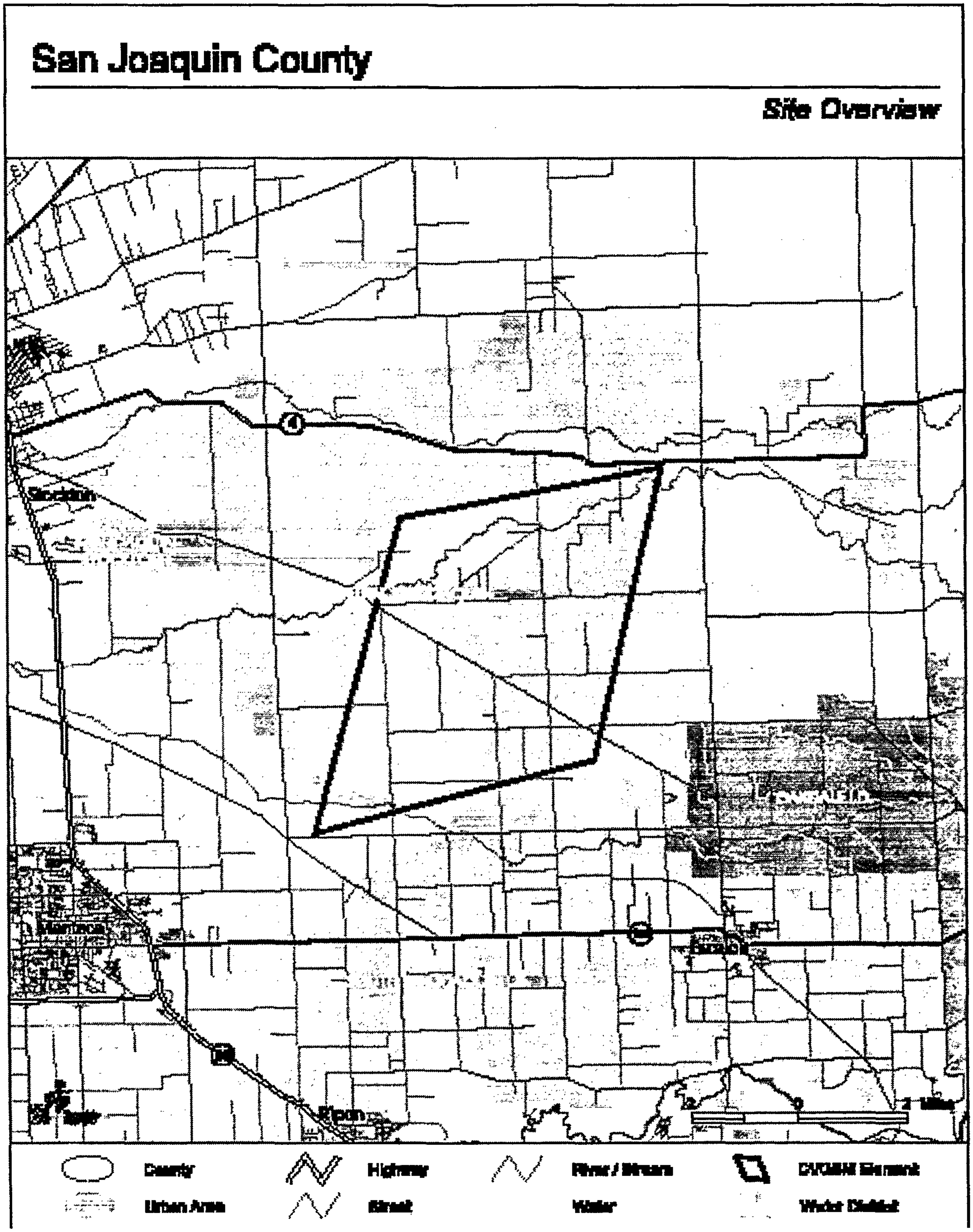
Figure 8



San Joaquin County
Site Overview
Stockton
Ripon
County
Highway
River / Stream
Urban Area
Street
Water
Water District

Figure 9

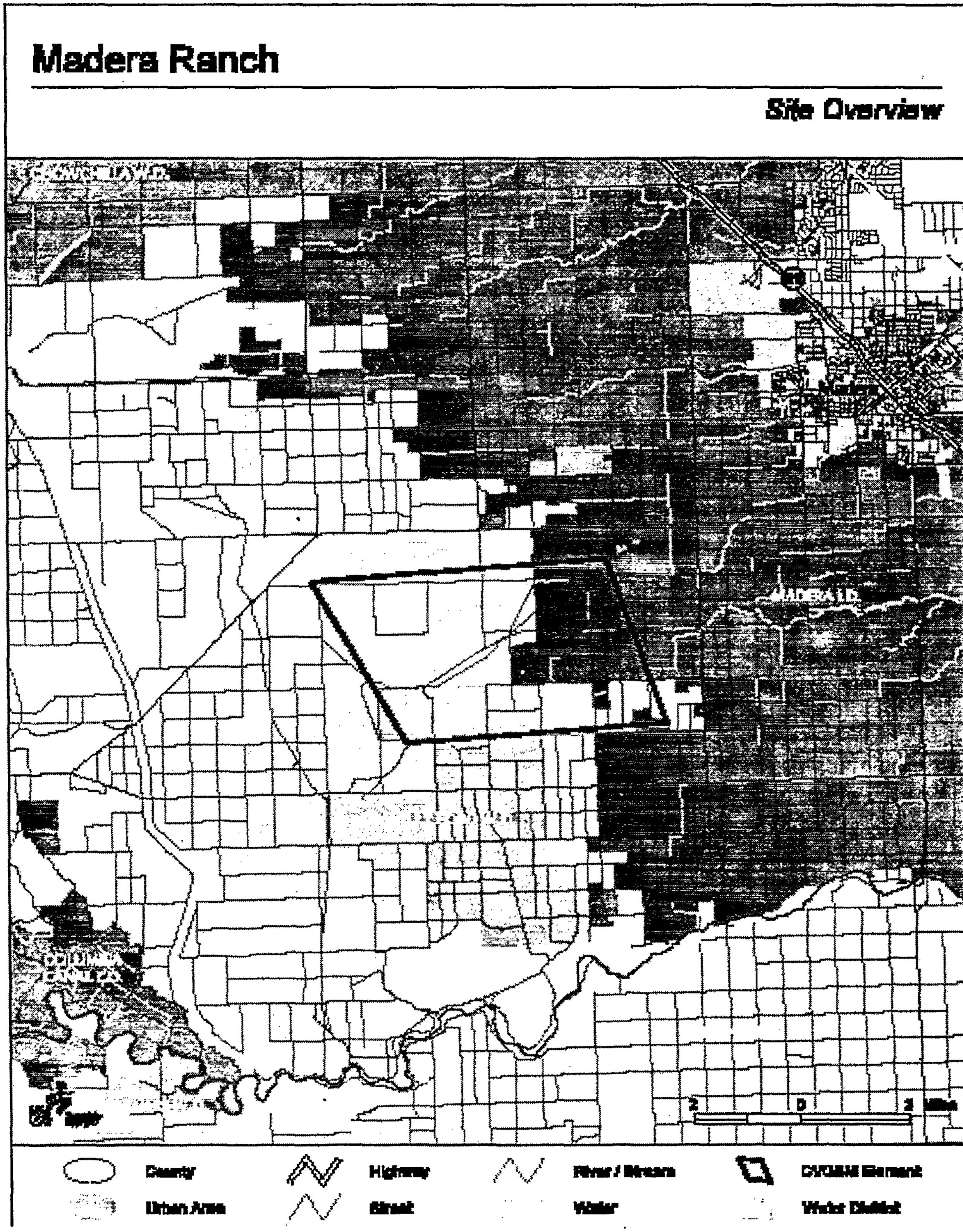


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Figure 10

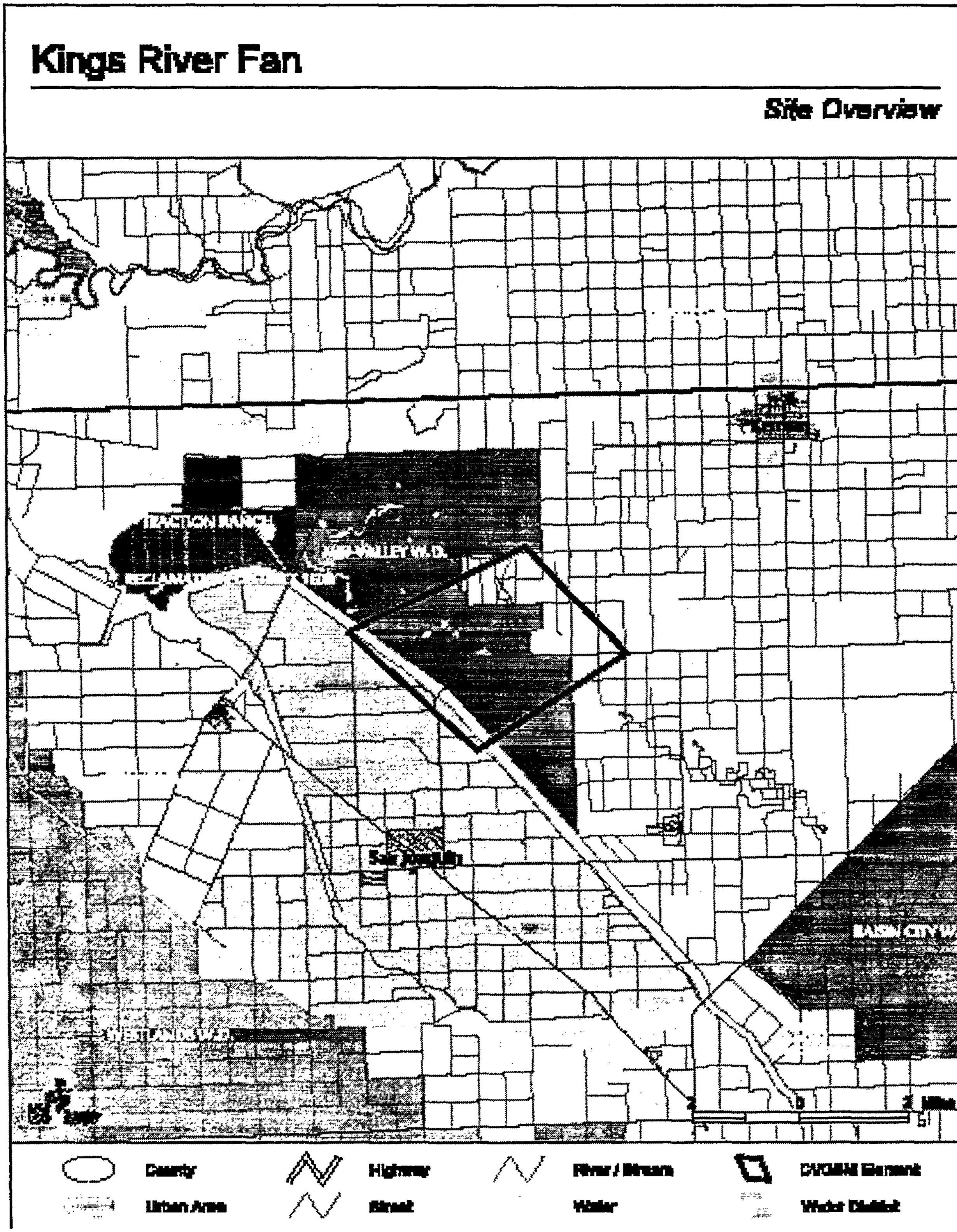

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Figure 11

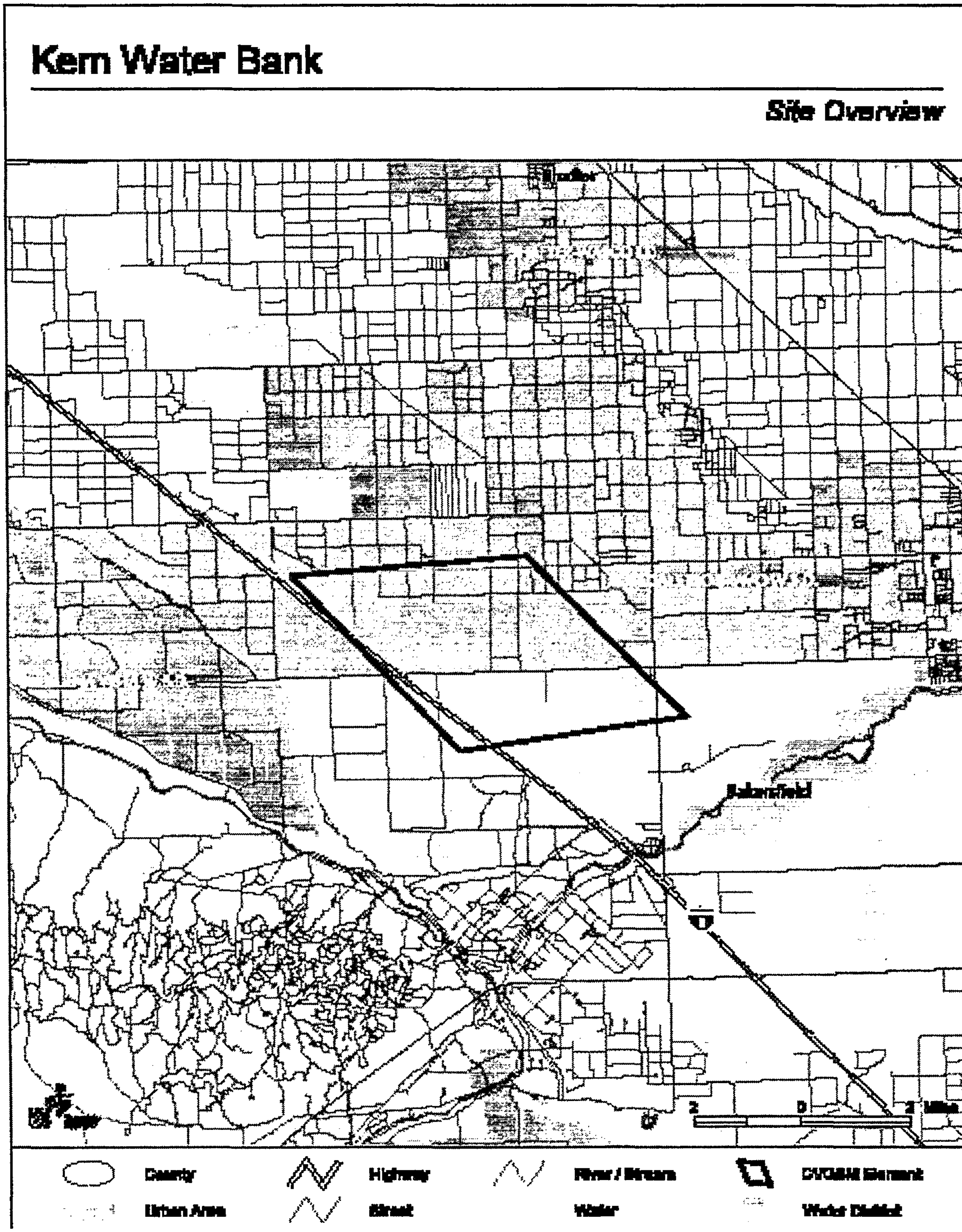

Figure 12
Total Estimated Project Capital Cost
Flow rate: 400 cfs, Recharge rate: 0.5 ft/day

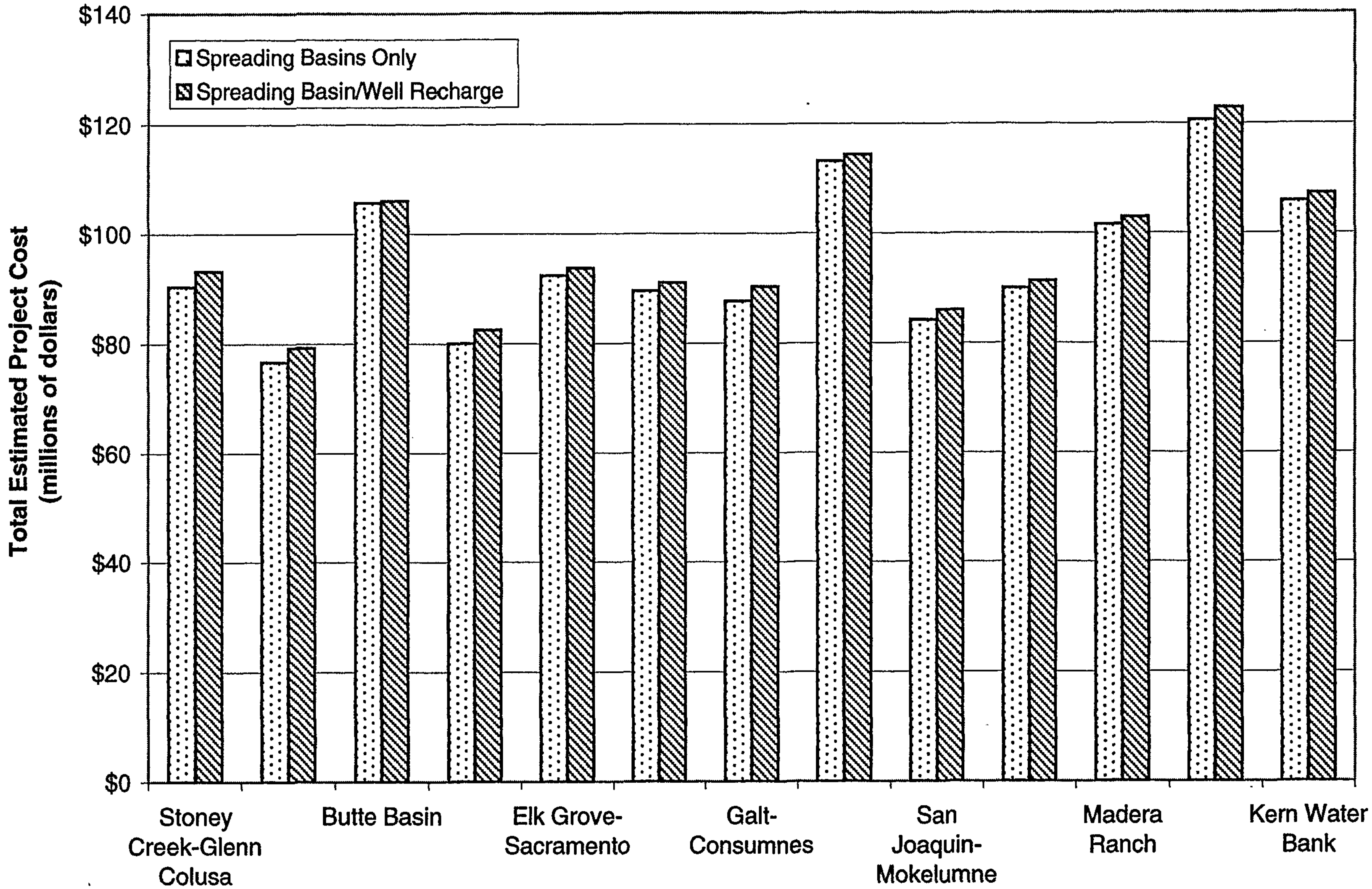

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Figure 13
Total Estimated Project Capital Cost
Recharge rate: 0.5 ft/day, Spreading Basin and Well Recharge

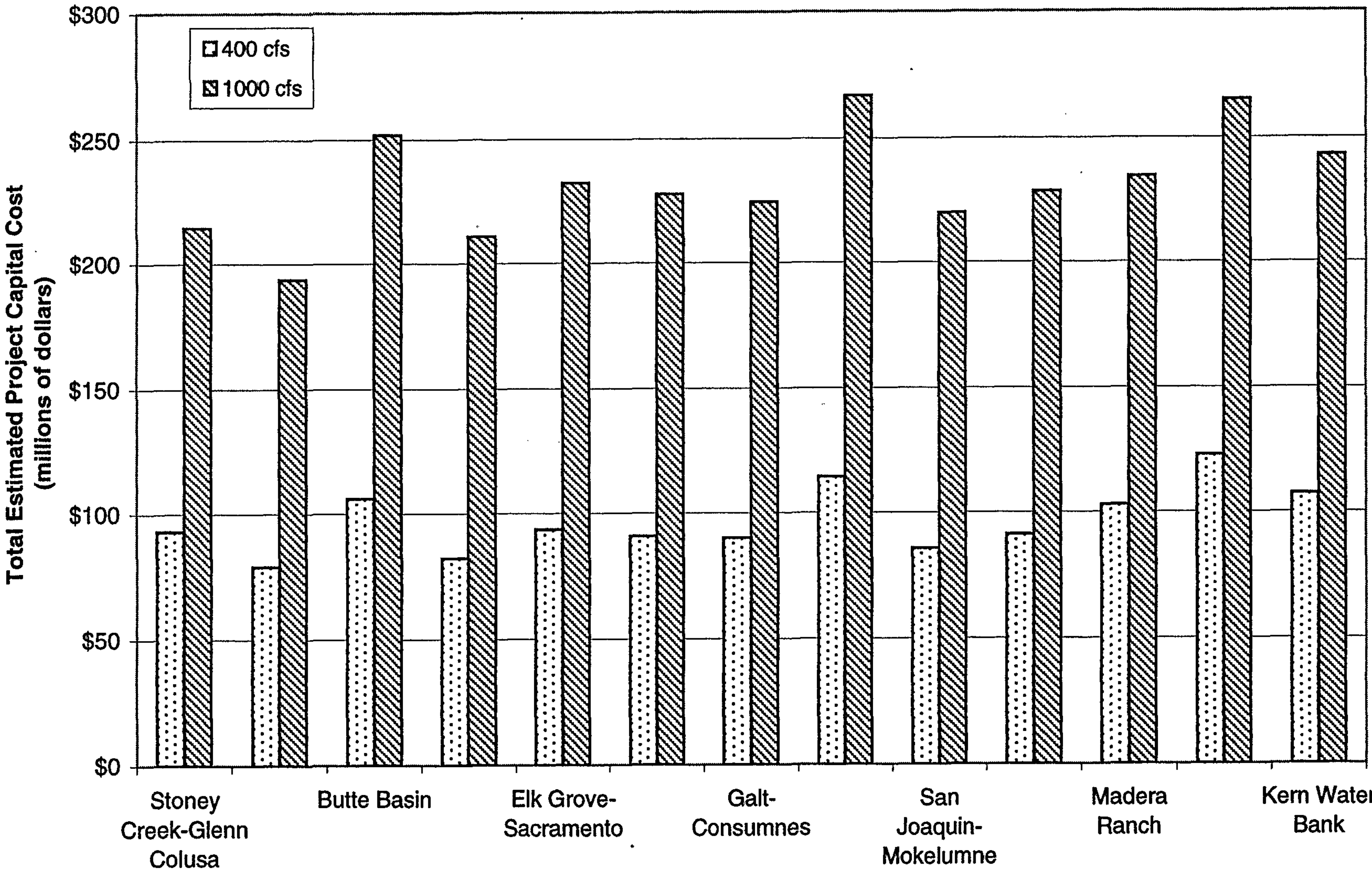

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Figure 14
Total Estimated Project Capital Cost
Spreading Basin and Well recharge, recharge rate: 0.5 ft/day

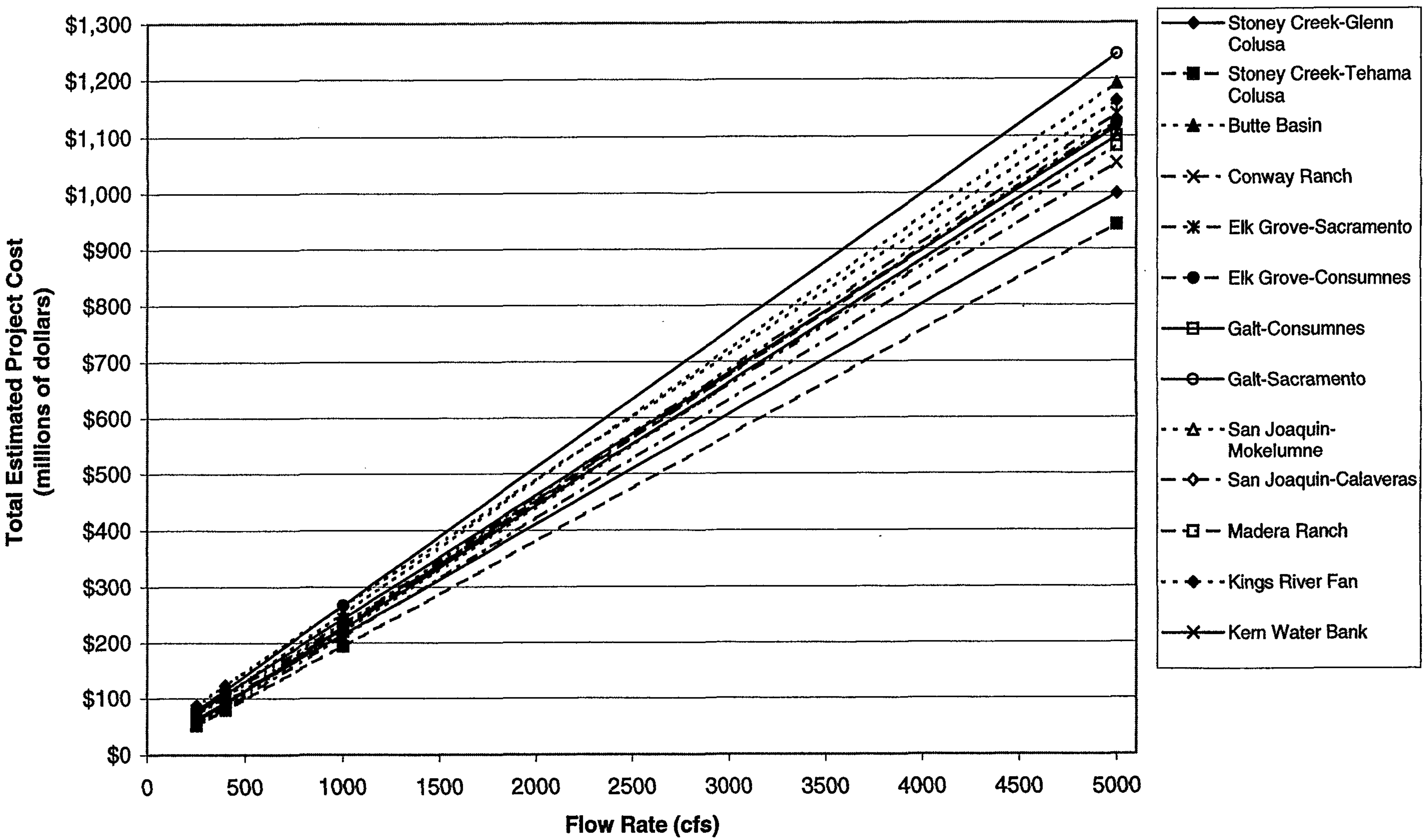

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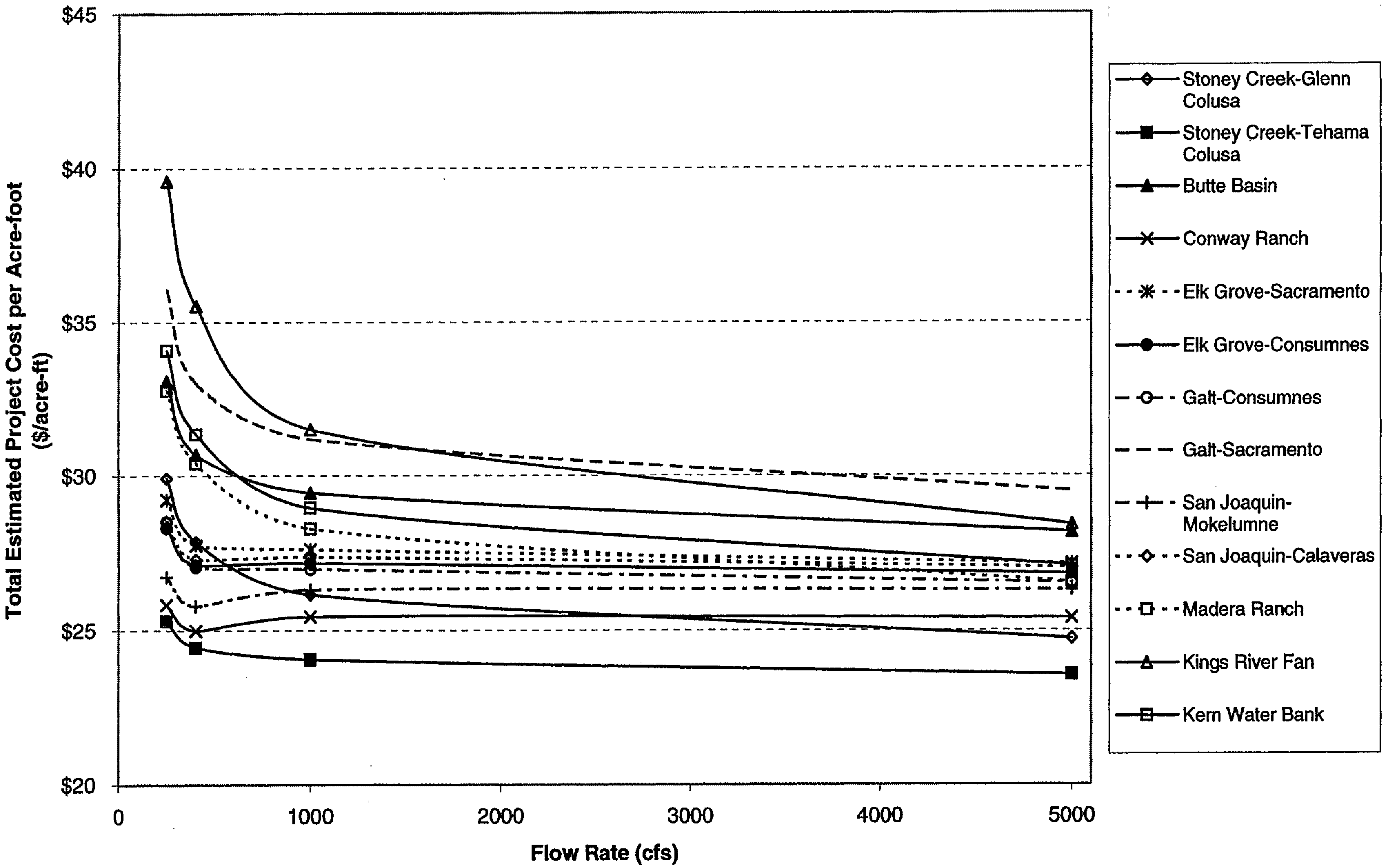
Figure 15
Total Estimated Project Cost per Acre-foot
Over Project Life of 30 years



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Attachment A
COST ESTIMATE APPROACH

OBJECTIVE

Order-of-magnitude cost estimates were developed for the sites identified by the screening process. These estimates are intended for use in the initial comparative analysis of the different project locations. More detailed, site-specific cost estimates need to be completed prior to additional planning efforts.

APPROACH

Potential project locations were located at or near the center of a cone of depression in the area, where present, or at an area identified from previous USBR work (Least-Cost CVP Yield Increase Plan, October 1995) or recently identified potential project site (Conaway Ranch). For each site, one or more take out locations were identified, as shown in Table 1.

TABLE A-1
Evaluated Project Sites and Potential Take-Out Sources

Site	County	Potential Take-Out Sources
Stony Creek	Glenn	Glenn Colusa Canal, Tehema Colusa Canal
Butte Basin	Butte	Thermalito Afterbay
Conaway Ranch	Yolo	Sacramento River
Elk Grove	Sacramento	Sacramento River, Cosumnes River
Galt	Sacramento	Sacramento River, Cosumnes River
San Joaquin County	San Joaquin	Mokelumne River, Calavaras River
Madera Ranch	Madera	California Aqueduct, Delta-Mendota Canal
Kings River Fan	Fresno	California Aqueduct
Kern Water Bank	Kern	Californa Aqueduct

Cost estimates were based on costing approach and information in other recent CALFED and USBR water project evaluations. These documents included the Madera Ranch Groundwater Banking Project – Cost Estimate Review (Stetson Engineers Inc., December 1998) and CALFED Storage and Conveyance Components Facility Descriptions and Cost Estimates (CALFED, October 1997).

Each project was assumed to consist of an intake structure (with fish screen where the intake structure was in the river), have a 2-way lined canal, and have recharge facilities consisting of either spreading basins or spreading basins and well injection. Full well injection was also initially considered, but it was found to be several times more costly than either of the first two recharge approaches, so it was dropped from further evaluation.

Costs were evaluated and extrapolated for take-out flows of 250, 400, 1000 and 5000 cfs to provide a range of potential flow and project sizes. Costs were identified for land value, operation and maintenance, filtration, well installation and intake structures. Costs for intake structures, bridges, crossings, siphons, and utility relocations were based on the previous works cited earlier.

A 1:100,000 topographical map was used to identify potential channel routes from the surface water source to the groundwater recharge site. Potential routes were generally the most direct and included the fewest number of road and waterway crossings.

Each project was broken down into its major components as identified in the Madera Ranch studies and evaluation by Stetson Engineers Inc., and previous CALFED surface storage cost studies. Assumptions were made for each component based on available data and then applied to individual projects. The project components identified include:

Canals

- Intake Structures/Fish Screens
- Pumping Plants
- Channel
- Road Bridges
- Irrigation Crossings
- Drainage Crossings
- Siphons (for highway, railroad and canal crossings)
- Utility Relocations
- Land
- Operation and Maintenance

Groundwater Recharge

- Land
- Spreading Basin Construction

Groundwater Extraction

- Wells
- Filtration
- Telemetry and Controls
- Operation and Maintenance

Cost allowances were made for contingency, engineering, administration, legal, and regulatory project components.

Cost Estimate Components

The cost estimate made numerous assumptions about recharge rates and project facilities. This information was based on available information and potential approaches to implementing conjunctive use projects. Specifics of the assumptions and project components are summarized in this section.

Project Cycle

For the purpose of this cost estimate the project cycle was assumed to be taking and recharging water for a period of 12 weeks annually for 5 of 7 years. Withdrawal of water was assumed to occur over 16 weeks annually over a 7 year cycle. Groundwater withdrawal was assumed to be at a rate of

Recharge was assumed to be completely by spreading basins or a combination of spreading basins and groundwater injection. To allow for the lack of uniformity in the rate of percolation in the spreading basins and locally within an area, costs were calculated based on three different percolation rates: 0.3 ft/day, 0.5 ft/day, and 0.7 ft/day. In the scenarios where groundwater injection was assumed, costs to filter the water were considered. Injection was assumed to occur at the wells constructed for groundwater extraction. Injection was assumed to occur at half the planned extraction rate.

Intake Structure

For projects that take surface water from rivers, fish screens are included as a part of the intake structure. Table A-2 shows the assumed costs for intake structures including fish screens.

TABLE A-2
Intake Structure with Fish Screen Cost Breakdown

Flow Rate (cfs)	Cost per unit flow rate ($/cfs)	Total Cost per Intake Structure
250	$7,500	$1,875,000
400	$7,500	$3,000,000
1000	$12,500	$12,500,000
5000	$15,000	$75,000,000

Cost estimates are based on CALFED Storage and Conveyance cost estimates, consultation with a CH2M HILL fish screen expert, and with Johnson Screens.

Intake structure costs for project sites that take water from canals or other locations not inhabited by fish are shown in Table A-3.

TABLE A-3
Intake Structure without Fish Screen Cost Breakdown

Flow Rate (cfs)	Total Cost per Intake Structure
250	$400,000
400	$500,000
1000	$1,000,000
5000	$4,000,000

TABLE A-3
Intake Structure without Fish Screen Cost Breakdown

Flow Rate (cfs)	Total Cost per Intake Structure
Cost estimates are based on Madera Ranch cost estimate and flow rates.	

Pumping Plants

Because canals were designed for bi-directional flow, pumping plants were necessary for every project. Pumping plants were assigned as a function of head loss over the entire system. One pumping plant was assigned for each 20 ft of head loss. Head loss was calculated based on elevation gain/loss from the take out point to the recharge point, length of channel, and an assumed loss for structures and intake elevation. A basic formula was applied to each site.

Head loss (ft) = Δ elevation (ft) + 2 ft/12 miles of channel + 3 ft/structure losses + 15 ft (intake and discharge Δ elevation)

Pumping plant costs were calculated at $2,000/hp. The formula used for pump cost is:

Pump Cost = (Flow rate (cfs) x Total Design Head (ft) x Unit conversion/Efficiency) x $2000/hp

Canals

Canal costs were calculated using the Madera Ranch cost estimates for 400 cfs canals. Channel dimensions were calculated for each flow rate, and unit costs extrapolated for each canal component. Each canal component was assigned a conversion factor based on the amount of material used in construction. For example, the canal lining is a function of the wetted perimeter, whereas the excavation volume is a function of cross-sectional area. Calculated costs were compared to the cost of the 5000 cfs canal from the Sacramento River to Lake Berryessa. Accordingly, an economy of scale factor of 0.85 was used to calculate the costs for the 5000 cfs canal. Dewatering and diversion during construction costs were not taken into account for the canal estimate.

Road Bridges

Cost for road bridges were made using the Bookman-Edmonston (B-E) Cost Estimate for Madera Ranch. No distinction was made between farm road bridges and county road bridges for this study. It was assumed that there would generally be more farm roads than county roads, and a cost per crossing was assigned based on channel flow rate.

TABLE A-4
Road Bridge Cost Breakdown

Flow Rate (cfs)	Cost per Road Bridge
250	$90,000
400	$100,000
1000	$125,000

TABLE A-4
Road Bridge Cost Breakdown

Flow Rate (cfs)	Cost per Road Bridge
5000	$250,000

Costs are based on B-E Madera Ranch estimates of farm road and county road bridges.

Siphons

Siphons were assumed for each highway, canal, and irrigation crossing. Reinforced concrete pipe was assumed and costs based on pipe numbers and dimensions necessary for each flow rate. The siphon length was assumed to be 700 feet for each highway crossing and 350 feet for both canal and railroad crossings.

TABLE A-5
Highway Siphon Cost Breakdown

Flow Rate (cfs)	Cost per Highway Siphon	Cost per Canal/Rail Siphon
250	$600,000	$300,000
400	$700,000	$350,000
1000	$1,500,000	$750,000
5000	$7,000,000	$3,500,000

Costs are based on CH2M HILL past project experience and the American River Crossing cost estimate.

Irrigation Crossings

Irrigation crossings were assumed at an interval of one every 0.75 miles.

TABLE A-6
Irrigation Crossing Cost Breakdown

Flow Rate (cfs)	Cost per Crossing
250	$20,000
400	$22,000
1000	$28,000
5000	$55,000

TABLE A-6
Irrigation Crossing Cost Breakdown

Flow Rate (cfs)	Cost per Crossing

Costs are based on the B-E Madera ranch estimate and scaled for flow rate.

Drainage Crossings

Drainage crossings were estimated based on the 1:100,000 topographical maps for each site.

TABLE A-7
Drainage Crossing Cost Breakdown

Flow Rate (cfs)	Cost per Crossing
250	$38,000
400	$43,000
1000	$55,000
5000	$110,000

Costs are based on the B-E Madera ranch estimate and scaled for flow rate.

Utility Relocation

One utility relocation was assumed necessary for each mile of canal length. The cost per relocation was the same for all flow rates, and assumed to be $20,000 based on the B-E estimate.

Land

County Assessors offices for each project site were contacted for general land values in the channel and spreading basin areas. No detailed cost analysis was performed. The values obtained are general and intended only for cost comparison purposes. The land values obtained are as follows.

TABLE A-8
Acreage Cost

Project Location	Cost per Acre
Stony Creek – Glenn Colusa	$2,000
Stony Creek – Tehama Colusa	$2,500
Butte Basin	$5,000

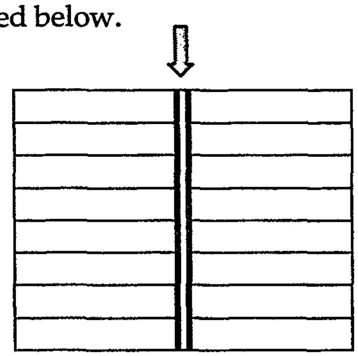
TABLE A-8
Acreage Cost

Project Location	Cost per Acre
Conaway Ranch	$2,500
Elk Grove – Sacramento River	$4,500
Elk Grove – Cosumnes River	$4,500
Galt – Sacramento River	$2,000
Galt – Cosumnes River	$4,000
San Joaquin – Mokelumne	$4,000
San Joaquin – Calaveras	$4,000
Madera Ranch	$4,000
Kings River Fan	$2,500
Kern Water Bank	$4,500

Land areas were calculated for each channel flow rate. Both channel width and spreading basin area were taken into account in the calculation of necessary land acreage

Spreading Basin Construction

Spreading Basins were designed in two rows of eight basins with water flowing in down the center of the rows as indicated below.



Earthwork calculations were based on excavation of 3 feet of soil over the entire area of the basin to remove less porous top surficial soil. Costs are based on developing basins capable of supporting a water depth of 8 feet.

Wells

All wells are assumed to be less than 500 feet deep and cost $350,000 per well. This value includes costs for drilling, installation, drilling and construction oversight, pump and pump housing. The well manifold system cost was assigned at $120,000 per well based on the B-E cost estimation. Telemetry and controls are not covered in this estimate.

Filtration

Filtration is necessary before water is injected into the aquifer. The cost for filtration is $41,000 per cfs.

Telemetry and Controls

Costs for telemetry and controls for were estimated at $150,000 per pumping plant.

Operation and Maintenance

Project operations and maintenance were calculated as energy cost, and replacement and maintenance cost over the life of the project. Energy costs were calculated for well extraction, injection and pump stations at $0.10/kW-hour. Replacement and maintenance was assumed to be 3% of the total estimated project capital cost per year.

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